Autonomic Neuroscience: Basic and Clinical 159 (2011) 117–122

Contents lists available at ScienceDirect

Autonomic Neuroscience: Basic and Clinical

journal homepage: www.elsevier.com/locate/autneu

Short-term heart rate dynamics of pregnant women

M.A. Peña [a,*], J.C. Echeverría [a], M.T. García [a], M.R. Ortiz [a], A. Martínez [a], C. Vargas-Garcia [c], R. González-Camarena [b]

[a] Electrical Engineering Department, Universidad Autónoma Metropolitana-Izt., Mexico City, Mexico
[b] Health Science Department, Universidad Autónoma Metropolitana-Izt., Mexico City, Mexico
[c] Maternal and Childhood Research Center (CIMIGen), Mexico City, Mexico

ARTICLE INFO

Article history:
Received 15 February 2010
Received in revised form 8 June 2010
Accepted 13 September 2010

Keywords:
RR dynamics
Scaling exponent
Pregnancy
Autonomic mechanisms

ABSTRACT

Aiming to detect the stage of gestation where dynamical changes of the RR fluctuations may occur, we assessed short-term fluctuations of low risk pregnant women. Ninety six, 10 min ECG recordings were collected along gestation (7 to 39 weeks). Corresponding RR fluctuations series were analysed to obtain the RMSSD, α_1, $\alpha_{1(mag)}$ and $\alpha_{1(sign)}$ parameters. Four groups covering first, second and last trimesters of gestation were conformed. No significant changes in α_1, which was close to unit, and $\alpha_{1(sign)}$ among gestational groups were identified. But, in accordance with previous findings, we did find a significant reduction of RMSSD along gestation, and significant short-term changes that indicate a higher degree of nonlinearity after about 26 weeks of gestation ($\alpha_{1(mag)}>0.5$)). These results suggest that the short-term heart rate dynamics of low risk pregnant women do not become compromised during gestation, despite the increased haemodynamic demands and other ongoing adaptations. Yet the complexity of the mechanisms involved in the cardiac regulation of pregnant women does seem to increase from mid-pregnancy, possibly owing to new short-term control influences or to modifications regardless the strength of the regulatory interactions.

1. Introduction

The RR intervals of the electrocardiogram show irregular and periodic fluctuations (Yamamoto and Hughson, 1991). Notwithstanding that intrinsic or extrinsic influences modify the behaviour of these fluctuations (Glass, 2001), their analysis by different techniques provide markers that some authors particularly associate with the autonomic control of the heart (Parati et al., 2006).

In several studies, changes in the RR interval fluctuations, which are also referred to as the heart rate variability (HRV), have been analysed to assess the autonomic condition of pregnant women. One could expect that the autonomic adaptations to fulfil pregnancy's haemodynamic requirements become clearly evident in the behaviour of the RR fluctuations. In fact, some authors have identified pregnancy changes in the RR fluctuations mainly associated with the aortocaval compression of late gestation, which is considered to cause an increase of the sympathetic influences on circulation (Chen et al., 1999; Kuo et al., 2000; Avery et al., 2001).

How can these changes be identified? Basically among other methods, by quantifying the magnitude or by assessing the structure of irregularity of the RR fluctuations along different scales through the use of fractal exponents. Recently, Yeh et al. reported in these pages that the RR fluctuations of late pregnant women involve lower magnitude and increased short-term fractal scaling exponent α_1 as compared with data collected 3 months after delivery, which return to show similar values of non-pregnant controls (Yeh et al., 2009). These findings introduce the need of detecting the stage of gestation where these dynamical changes of the RR fluctuations may occur, with the aims of exploring in more detail the potential meaning that such fluctuations convey regarding the cardiovascular regulation during pregnancy.

Here we analyse short-term RR fluctuations collected at early, mid and late gestation from low risk pregnant women to identify dynamical changes of the RR fluctuations during pregnancy.

2. Methods and recordings

2.1. Subjects

Ninety six singleton pregnancies without complications according to their clinical history, physiological assessment, and blood sample test were studied at CIMIGen.[1] Gestational age ranged from 7 to 39 weeks and women aged 25 ± 6 years old. All gave their informed consent to collect once during their gestation 10 min of ECG data at 45° semi-Fowler position with extended legs. Recordings were performed during morning hours (9–12 h) in a clinical environment. 51 cases of the studied pregnancies had no history of previous

* Corresponding author. Electrical Engineering Department, Universidad Autónoma Metropolitana-Izt., San Rafael Atlixco #186, C.P. 09340, Mexico City, Mexico. Tel.: +52 55 58044632; fax: +52 55 58044628.
E-mail address: mapc@xanum.uam.mx (M.A. Peña).

[1] Maternal and infant clinical research center, Mexico City.

1566-0702/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.autneu.2010.09.006

gestations, 31 cases were coursing the second gestation, and 14 cases had history of more than two gestations.

Four groups along gestation were conformed in accordance with the classification of the recordings' week by the k-means clustering algorithm (Table 1). This algorithm was applied to achieve a classification driven by the independent variable (*i.e.* the week of gestation) and not biased by any physiological change expected. Such classification introduced a more even covering of gestation among groups (Fig. 1). Note that, whereas group G1 covers the first trimester of gestation, G2 includes cases from the second trimester, and G3 spans within the second and last trimesters. G4 involves cases studied during the last trimester of gestation.

2.2. RR intervals

The 10 min ECG recordings were collected by standard methods and sampled at 1 kHz (Nihon Kohden AB621G and Biopack MP100). To obtain RR fluctuations series, suitable for HRV analysis, all of the RR intervals were automatically detected, yet manually verified for excluding noise and beats of no sinus origin. 14 out 96 series presented missing RR intervals, but the average number of these intervals was not larger than 2%. For all cases studied 600 samples RR fluctuations series were obtained from the beginning of ECG recordings.

Notwithstanding the estimation of the following HRV scaling parameters may be improved by analysing long data series, collecting longer recordings would result impractical for antenatal studies. In fact, the duration of time series analysed in the preceding study regarding the RR dynamics of pregnant women (Yeh et al., 2009) was also about 10 min.

2.3. HRV analysis

Whereas to quantify the RR fluctuation series the RMSSD parameter was calculated, the irregular fractal structure of the data was evaluated by applying detrended fluctuation analysis (DFA). The mean of the RR fluctuations series was also obtained (RR_{mean}). The former parameter was estimated by the root-mean-square of successive RR interval differences.

DFA provided the scaling exponent α_1 as detailed elsewhere (Peng et al., 1995). Briefly, the RR fluctuations series were integrated and divided into subsets of independent and locally detrended segments by a least-squared line fit, with each segment having an equal numbers of n RR intervals. The average root-mean-square fluctuation $F(n)$ was calculated for different segment sizes (time scales). The relationship on a double-log graph between $F(n)$ and time scales n was approximately evaluated by a linear model $F(n) \sim n^{\alpha_1}$, thereby providing the scaling exponent α_1 as the slope of the plot covering the short-term range of n from 4 to 11 intervals (in accordance with (Yeh et al., 2009)). The scaling exponent may vary from 0.5 (uncorrelated fluctuations, white noise) to 1.5 (smoother fluctuations). A value near 1 indicates the existence of fractal-like correlations.

Given that α_1 only offers information about linear scaling characteristics, the RR fluctuation series were further explored to assess the nonlinear properties or time ordering. This assessment was achieved by applying the so called scaling magnitude and sign analyses

Table 1
Number of recordings analysed for each gestational group. Also indicated are the mean gestational weeks covered by these groups.

	N	Gestation weeks (mean ± SD)
Group 1 (G1)	18	10 ± 2
Group 2 (G2)	25	17 ± 2
Group 3 (G3)	27	28 ± 2
Group 4 (G4)	26	35 ± 2

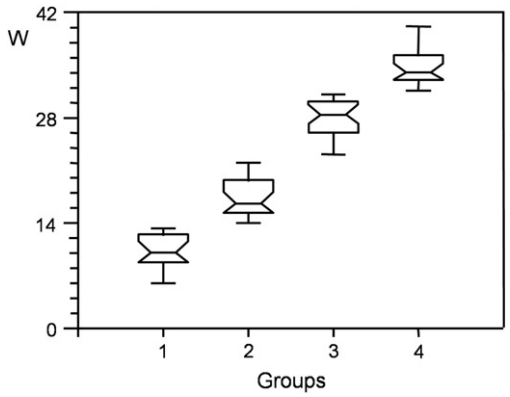

Fig. 1. Box plots to show how gestation was covered among four groups in accordance with the classification of 96 studied cases. This classification was achieved by a k-means clustering of the cases' week of gestation (W).

(Ashkenazy et al., 2001). Accordingly, the original RR fluctuations were processed to obtain increment series by taking the differences between adjacent intervals ($RR_{i+1} - RR_i$). These series (ΔRR) were decomposed into magnitude $|\Delta RR|$ and sign series $sign(\Delta RR)$. After subtracting their respective means, magnitude and sign series were integrated and DFA was again applied as described above. The slope of $F(n)/n$ covering the range from 4 to 11 intervals then provided magnitude and sign scaling exponents ($\alpha_{1(mag)}$ and $\alpha_{1(sign)}$, respectively). Positive correlations in magnitude series (*i.e.* finding $\alpha_{1(mag)} > 0.5$) have found to be a reliable marker of nonlinear properties (Ashkenazy et al., 2003). The $\alpha_{1(sign)}$ exponent provides information about the temporal organisation of the original series in relation to the way series' increments alternate, indicating if a positive or negative increment is more likely to occur given a current increment (Ashkenazy et al., 2001, 2003).

2.4. Statistical analysis

Significant differences of RR_{mean}, RMSSD, α_1, $\alpha_{1(mag)}$ and $\alpha_{1(sign)}$ among gestational groups were evaluated by one-way Kruskal–Wallis ANOVA owing to residuals not normally distributed in most but not all parameters($\alpha_{1(sign)}$). Significance was considered by $p < 0.05$. Post hoc pairwise differences were determined by equal-variance t-test.

The Spearman's rank correlation coefficients among all parameters as well as the weeks of gestation were also estimated.

3. Results

In Fig. 2 typical RR data and corresponding results regarding RR_{mean}, RMSSD, α_1, $\alpha_{1(mag)}$ and $\alpha_{1(sign)}$ for groups G1–G4 are shown. Note that the RR fluctuations become reduced with advanced gestation.

Whereas in Fig. 3 the box plots of the four groups for all studied parameters are presented, in Table 2 p-values and power provided by statistical tests of these parameters are summarised. No significant changes among gestational groups were detected for the parameters α_1 and $\alpha_{1(sign)}$, but this was not the case for RR_{mean}, RMSSD and $\alpha_{1(mag)}$ both changing from about mid-pregnancy.

The Spearman's rank correlation coefficients (r_s) among the RR data parameters, which were calculated from all series ($N = 96$) collected along gestation, regardless of corresponding gestational group, are included in Table 3. Lack of significant correlations between parameters were only identified for α_1 *vs* $\alpha_{1(mag)}$, as well as α_1 (or $\alpha_{1(sign)}$) *vs* the week of gestation.

4. Discussion

One of the main findings of this contribution is that, contrary to what was expected in relation to previous studies, and despite finding